Using FTA to reduce capital cost of safety

Waguih Zaky
WZAKY TECH SERV
613 498 7043

Summary

Chemical plants have been improved over the years through equipment changes, installation of more backup or redundant systems, use of DCS to provide better information and the ability to recall historical data to review incidents and improvement in safety review methodology. Quite often these improvements are not credited appropriately and more elaborate safety features are still added or called for without taking credit for the previous improvements.

In this case I would like to present a situation where the normal approach would have required a significant investment in a dump Tank to contain the reaction products in the event of an emergency.

A quantitative FTA was completed to detect where weaknesses in the defenses existed and to show that many of the safety features added over the years had indeed eliminated the need for a new dump tank. This improved the safety of the process beyond the original scope dump tank and cost about 20% of the original scope.

Background Information

In the plant ingredient A reacts with ingredient N to produce product C and gases G with byproduct B and another byproduct W. The heat of reaction is removed by circulating the reaction mixture through a shell and tube heat exchanger. A separator is used to separate the off gas produced in the reaction from the circulating liquid. The off gas is processed further to recover useful products before venting. The reaction must be completed in a great excess of N to ensure complete reaction. The liquid from the reactor flows to next stage of refining where the product is separated from the excess reactant N. A purge stream is taken from the returned liquid N to separate the undesirable byproducts and recycle the unreacted product N. Fresh reactant N is added to the regenerated and recovered N from refining process.

The part of the process of interest is the reactor system itself. This consists of a large circulating pump circulating a large flow through a water cooled shell and tube heat to remove the heat of reaction. The two ingredients A and N are injected after the pump before the heat exchanger. The reactants react rapidly and release the heat of reaction which is removed in the heat exchanger. The liquid from the heat exchanger enters the separator where vapor is separated from the liquid. The liquid provides feed for the pump. The gases flow to the recovery system. The liquid product from this reaction is allowed to flow from the discharge of the pump ahead of injecting the fresh ingredients to the next processing stage.

The hazards of the process

The hazards in this process are known to be:

- Passing incomplete reaction products from the reaction system to downstream equipment not designed for this reaction. This can be caused by
    - insufficient excess of ingredient N
    - low temperature
- High temperature resulting in a runaway reaction and explosion
    - Due to a loss of cooling
    - Dead heading pump
    - Loss of circulation through the heat exchanger due to pumping problems or pluggage
- Overpressure causing the Rupture Disc to open to atmosphere
    - Closure of off gas control valve
    - Pluggage in vent line
    - Entrainment from separator due high level or foaming
- Back up of ingredient N into the supply line of ingredient A
- The accumulation of free or excess unreacted A in solution of N
- Large uncontrolled leak from equipment to ground or sewers
- Allowing the reaction to occur without adequate dilution through lack of circulation or lack of excess ingredient N.

In the original design it was considered prudent to provide an ability to dump the reaction products under certain adverse conditions into an underground dump tank where diluents can be added to stop the reaction. However this is usually accompanied by a release of undesirable gases to atmosphere. It was considered prudent to upgrade this to a pressurized system to avoid the potential for atmospheric release.

The Existing safety features

As a result of understanding the safety problems faced, many features were added over the years. These included:

- High temperature interlock on the pump to detect a dead head situation
- Reliable flow meter in the circulating loop to detect loss of circulation
- Redundant level indications in the separator to avoid entrainment or pump cavitations
- Use flushing liquid to keep level instruments working reliably
- Providing field indication of level instrument flush flow
- Providing better double mechanical pump seal with buffer flush
- Providing pump seal flush with local field indication of
    - seal flow in
    - seal flow out
    - seal flush pressure
- Providing multiple temperature indication on the reactants in and out of the heat exchanger to ensure reaction does not get too cold or too hot with interlocks
- Providing redundant high reliability mass flow measurement of ingredients A
- Providing automatic double block and bleed valve in addition to the flow control valve on the feed A
- Providing a diluent flush into the feed line of ingredient A to provide separation A from N upon startup or shutdown
- Provide measurement of redundant flow measurement of flow N
- Provide double automatic shutoff valve on ingredient N

Fault tree and changes made

The fault tree was prepared on the basis of this known list of hazards and the safeguards that have been provided. Based on the existing hardware it was estimated that several of failures would occur at reasonably high frequencies because either there were areas where there was not adequate redundancy like the air injection to sweep the process or because we had field indications of process seal flushes and hence it likely that problems will eventually occur that are not detected and corrected in time before they cause a significant pump seal failure or level instrument failure.

1. The FTA showed that a runaway reaction is not a credible event because of the multiple measurements and the redundant shutoff of ingredients. Therefore, the use of RD instead of a RV was not required. Installation of an RV alone would be possibly unreliable because of the buildup of solids in the throat. Therefore an RD with an RV above it with leak detection was chosen. This eliminated the high frequency of release to atmosphere due over pressure, or to failure of RD due to corrosion or incorrect installation or manufacturing defect. The RD protects the RV and the RV limits the release after an event.
2. The air sweep injection used only one valve to stop flow on high pressure. The second main header control valve was engaged in the interlock to provide redundancy.
3. In order to shutoff the flow of ingredient N when required there was only one flow control valve used for shutoff. It was decided to shutdown the pump and close the main feed Shutoff valve to improve reliability.
4. The reliability of the level measurements was improved by installing DCS monitored purge flush measurements with alarms and separating the purge flows to each instrument leg.
5. The pump seal reliability was improved by adding DCS monitored flow indications on the seal flush in and seal flush flow out. The seal flush temperature in and out were also monitored in DCS and alarmed installed. The seal pressure was provided with redundant pressure measurements to detect a seal failure. With the above checks in place, we were able to monitor the status of the seal and detect a seal failure into the process or outside to atmosphere. The pump already had high temperature detection and interlocks as well as vibration monitor on the motor and pump with interlocks.
6. To ensure that the flow of N is adequate a second flow meter in the exit of the Reactor was provided as a redundant backup.

As a result of the above mentioned improvements, we believe that we actually reduced the likelihood of events that would result in releases to atmosphere or injury to personnel by about 100 fold achieving this improvement with only about 20% capital versus the standard option.

On startup, we detected an imbalance in the pump seal flow in versus flow out. This indicated a seal failure. This was corrected.

Also on startup, the RD had been installed incorrectly. This was detected through the pressure rise between the RD and RV. This was also corrected.